Field Expedient Water Treatment with Sodium Hypochlorite for Use in Irrigation of Open Wounds and Fractures

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Objective:

Currently accepted practice promotes early irrigation and surgical debridement of high energy wounds and open fractures as an effective means of preventing infection. To decrease the time from wounding to surgical care, the United States military utilizes forward surgical teams, a key feature being their small size and limited resources. If sterile saline is used for irrigation, the volume required to treat multiple patients with multiple wounds presents a significant logistical burden. Use of a field-expedient irrigation solution using ground-derived field water could eliminate this logistical burden. For this study, we collected 100 water samples from 5 different sources of water (free-standing lakes/ponds and running sources). An initial total bacterial count (CFU/ml) was determined prior to treatment. The samples were subsequently treated by adding 5% sodium hypochlorite (common household bleach) to derive a concentration of 0.025%. After treatment, all samples had a bacterial colony count performed. We found no bacterial growth in 99/100 samples. One post-treatment sample grew a single colony of a Bacillus species not present in the pre-treatment culture (likely an air contaminant). Our field-expedient modification of "Dakin's solution," made from a locally obtained water source, including ground water if necessary, could substitute for sterile irrigation fluid if it is neither available nor logistically feasible. This process may eliminate the need to carry large volumes of irrigation fluid forward.

Introduction

To decrease the time from wounding to surgical care, the United States military developed forward surgical teams, which are notable for their small size and limited resources. The role of the surgeon initially treating high-energy soft tissue wounds and open fractures is to provide primary wound care through prompt surgical debridement of devitalized tissue and copious lavage.[1-7] Early irrigation and debridement of open wounds/fractures effectively prevents bacterial infection. [1-7] The common use of approximately ten liters of irrigant for the lavage of each wound, imposes the significant logistical burden of carrying large amounts of sterile irrigation preparations for use as irrigants in treating wounds and open fractures. The current method of providing irrigation fluid in the field involves transporting sterile saline or using locally obtained potable water. The transport burden of carrying irrigation fluid items would be eliminated if a safe and effective method of sterilizing available field water sources existed for wound irrigation, while preventing the adverse effects of tissue toxicity on tissues as a result of bactericidal additives. Kleblish and DeMaio[8] have suggested any source of water may be used to

prepare sterile irrigant. No study has formally evaluated the effectiveness of treating ground-derived field water with hypochlorite for use in irrigating open wounds and fractures. We set out to determine if available water sources in the field could be used to make an acceptable field-expedient "Dakin's solution." Specifically, we sought to determine if locally obtained ground water treated with 5% sodium hypochlorite (common household bleach) could result in a sterile, bactericidal, nontoxic irrigant, thus eliminating the logistical burden of transporting sterile water for wound irrigation.

The care of combat wounds has advanced greatly since 1915 when Anton von Eiselberg, promoted the concept that "the fresh wound must not be touched with the finger and no antiseptics must be applied to it..."[9]. At the same time, Henry Dakin, in a collaborative effort with Alexis Carrel, sought to maximize the treatment of wounded French soldiers by using a buffered sodium hypochlorite 0.05% solution.[9] They noted a dramatic decline in deaths and amputations after using a regimen of wound debridement, irrigation, and delayed closure. Their findings forever changed the face of wound care, and resulted in a hypochlorite solution (Dakin's solution) that has a long history of use worldwide.

Hypochlorites have a wide antimicrobial efficacy against both gram-positive and gram-negative bacteria as well as viruses, fungi, and spores, without formation of resistant organisms.[10,11] Hypochlorous acid is the active moiety of sodium hypochlorite and is felt to exert its effect by oxidizing essential enzymes in the microbes.[11] Previously, Cotter et al. performed an in vivo animal study which showed marked epidermal hyperplasia with solutions of 0.1% to 0.5% sodium hypochlorite.[12] Kozol et al. subsequently reported a concentration of 2.5×10^{-2} to 2.5×10^{-4} damaged fibroblasts and endothelial cells and impaired neutrophil chemotaxis.[13] Lineaweaver et al. reported survival of fibroblasts and antibacterial properties of solutions with a NaOCl concentration of 0.5×10^{-2}.[3,4] In 1991 Heggers et al. definitively demonstrated a solution of 0.025% sodium hypochlorite could provide a sterile, bactericidal irrigant for wounds while having no deleterious effects on tissues or healing.[14] They found NaOCl concentrations of 0.25% and 0.025% were bactericidal, but only the 0.025% solutions maintained fibroblast cytoarchitecture and viability.

As determined in the study by Heggers et al., a sodium hypochlorite concentration of 0.025% is both bactericidal and non-toxic to tissues.[14] With this in mind, we performed our study to determine what level of microorganisms in field water can be killed by adding sodium hypochlorite to a concentration of 0.025% to create an irrigant for wartime situations when sterile solutions are neither available nor logistically feasible. This preparation may also be useful in the event of mass casualties after available sterile solutions have been depleted.

Methods

We collected water samples from 5 different sites (3 lakes/ponds and 2 creeks). At each site, twenty 30 ml samples were collected from a depth between the surface and the bottom to limit heavy fungal and bacterial loads as recommended by the Military Public Health Office. Samples were then strained through cheesecloth to simulate field conditions for the removal of large, extraneous debris. An initial inoculation from each sample to sheep-blood agar was performed. These plates were incubated overnight at room temperature with a subsequent total bacterial count (CFU/ml) performed to determine base levels of bacterial contamination of the 100 samples. The samples were then treated by adding 5% sodium hypochlorite to derive a

concentration of 0.025% (5 cc of bleach per Liter of water). The culture process was repeated, and a final total bacterial count was performed. Sterile water served as a negative control.

Results

Prior to treatment, all specimens exhibited bacterial culture growth, ranging from 5.6×10^1-5.1×10^7 with a mean of 12.4×10^3 CFU/ml. Following treatment with hypochlorite, there was no bacterial growth in 99/100 samples (Table 1 & Figure 1). One sample (Site 4, sample #18), grew a solitary colony of a Bacillus species. This was likely an air contaminant as the Bacillus morphology was not present in the pre-treatment culture of this sample.

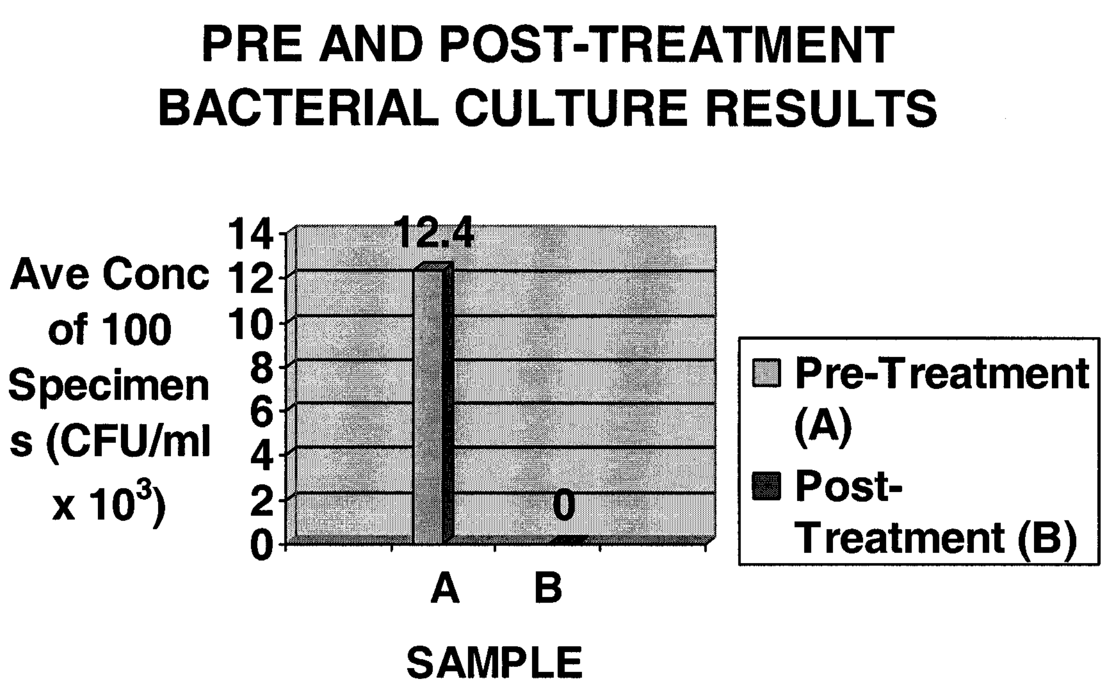
TABLE 1: Pretreatment and Posttreatment Bacterial Culture Results

Site 1 Sample	Concentration CFU/mL Pretreatment	Posttreatment	Site 2 Sample	Concentration CFU/mL Pretreatment	Posttreatment	Site 3 Sample	Concentration CFU/mL Pretreatment	Posttreatn
1	7.45E+02	0.00E+01	1	4.20E+03	0.00E+01	1	3.70E+03	0.00E+0
2	9.90E+03	0.00E+01	2	6.70E+03	0.00E+01	2	6.60E+03	0.00E+0
3	6.30E+03	0.00E+01	3	3.70E+03	0.00E+01	3	1.15E+04	0.00E+0
4	3.10E+03	0.00E+01	4	4.30E+03	0.00E+01	4	5.90E+03	0.00E+0
5	1.16E+03	0.00E+01	5	3.50E+03	0.00E+01	5	6.90E+03	0.00E+0
6	3.40E+03	0.00E+01	6	1.72E+03	0.00E+01	6	1.30E+04	0.00E+0
7	9.10E+03	0.00E+01	7	8.50E+03	0.00E+01	7	4.80E+03	0.00E+0
8	1.10E+03	0.00E+01	8	9.50E+03	0.00E+01	8	9.00E+03	0.00E+0
9	1.01E+03	0.00E+01	9	9.10E+03	0.00E+01	9	9.40E+03	0.00E+0
10	2.60E+03	0.00E+01	10	6.00E+03	0.00E+01	10	7.50E+03	0.00E+0
11	2.90E+03	0.00E+01	11	4.90E+03	0.00E+01	11	5.70E+03	0.00E+0
12	1.04E+03	0.00E+01	12	3.40E+03	0.00E+01	12	5.00E+03	0.00E+0
13	1.06E+03	0.00E+01	13*	1.18E+05	0.00E+01	13	7.80E+03	0.00E+0
14	3.90E+03	0.00E+01	14	7.40E+03	0.00E+01	14	7.10E+03	0.00E+0
15	2.50E+03	0.00E+01	15	7.70E+03	0.00E+01	15	5.10E+07	0.00E+0
16	1.15E+03	0.00E+01	16	7.60E+03	0.00E+01	16	7.90E+03	0.00E+0
17	3.60E+03	0.00E+01	17	4.40E+03	0.00E+01	17	6.20E+03	0.00E+0
18	2.50E+03	0.00E+01	18	6.10E+03	0.00E+01	18	1.06E+04	0.00E+0
19	1.16E+03	0.00E+01	19	3.90E+03	0.00E+01	19	7.70E+03	0.00E+0
20	2.60E+03	0.00E+01	20	6.10E+03	0.00E+01	20	8.20E+03	0.00E+0
Negative control	0.00E+01	0.00E+01	Negative control	0.00E+01	0.00E+01	Negative control	See Site # 5	

Site 4 Sample	Concentration CFU/mL Pretreatment	Posttreatment	Site 5 Sample	Concentration CFU/mL Pretreatment	Posttreatment
1	8.20E+03	0.00E+01	1	3.10E+03	0.00E+01
2	5.30E+03	0.00E+01	2	2.70E+03	0.00E+01
3	3.20E+03	0.00E+01	3	3.20E+03	0.00E+01
4	6.00E+03	0.00E+01	4	3.20E+03	0.00E+01
5	6.10E+03	0.00E+01	5	2.40E+03	0.00E+01
6	9.40E+03	0.00E+01	6	2.40E+07	0.00E+01
7	7.90E+03	0.00E+01	7	5.60E+03	0.00E+01
8	6.80E+03	0.00E+01	8	5.90E+03	0.00E+01
9	6.30E+03	0.00E+01	9	5.50E+03	0.00E+01
10	5.60E+01	0.00E+01	10	5.00E+03	0.00E+01
11	1.04E+04	0.00E+01	11	6.40E+03	0.00E+01
12	5.10E+03	0.00E+01	12	4.80E+07	0.00E+01
13	7.60E+03	0.00E+01	13	6.40E+03	0.00E+01
14	9.70E+03	0.00E+01	14	2.60E+03	0.00E+01
15	8.00E+03	0.00E+01	15	8.90E+03	0.00E+01
16	9.90E+03	0.00E+01	16	3.70E+03	0.00E+01
17	6.60E+03	0.00E+01	17	7.30E+03	0.00E+01
18*	7.20E+03	5.00E-00	18	4.90E+03	0.00E+01
19	8.10E+03	0.00E+01	19	5.00E+03	0.00E+01
20	5.50E+03	0.00E+01	20	4.30E+03	0.00E+01
Negative control	See Site # 5		Negative control	1.00E+01	0.00E+01

*Number 18: Posttreatment culture had 1 colony Bacillus sp on plate. Predominant morphology type on this culture was a small white colony that was not like the colonial morphology found on the plates of the other sample cultures from this site. This suggests that there was contamination of this sample at some point in the dilution and plating process resulting in a concentration that is not consistent with the other samples from this site.

Figure 1.



Discussion

During military combat, penetrating wounds to the limbs predominate.[5] High energy war wounds and open fractures are all contaminated and frequently involve open fractures.[16,17] These wounds require prompt surgical treatment in the form of surgical debridement of devitalized tissues and copious irrigation, followed by stabilization of fractures when indicated.[16,17] Adjunctive antibiotic therapy should also be provided.[5] During Desert Storm, the average time from injury to arrival at echelon II facilities was 4.5 hours.[8,15] Treatment in such scenarios typically involved antibiotic prophylaxis, sterile dressings, and splinting. However, these measures alone, without adequate surgical debridement and irrigation, will not sufficiently reduce the risk of infection.[2,8,18] Jacob et al. performed a retrospective analysis of 37 open fractures sustained by U.S. military personnel during the military conflict Operation Just Cause in Panama. Their study noted a significant difference between the infection rate for type III open fractures that were debrided in Panama (22%) versus those that were debrided after transport (66%), thus emphasizing the importance of early surgical debridement in preventing infections in war wounds.[19]

The United States military recently developed Forward Surgical Teams to provide prompt definitive care of the wounded soldier in the field. In addition to prompt life saving procedures, these teams can provide early primary surgical wound care. Teams are limited with respect to the amount of supplies they carry, and must balance the amount of supplies needed to adequately care for the wounded soldier while limiting the weight and bulk of their supplies. The weight and space required to transport the required volume of sterile saline (approximately ten liters per wound) becomes prohibitive. This would make it impossible to carry supplies sufficient to care for multiple wounds in multiple patients. This preparation is easily made by adding 5 cc of 5% (common household bleach) per liter of water or 50 cc for the standard 10 Liter preparation.

Conclusion

Our findings provide substantial evidence that treating locally available water with sodium hypochlorite to a concentration of 0.025% effectively prevents microbial growth. These findings verify past studies which proved this 0.025% concentration of hypochlorite is bactericidal.[14] This hypochlorite solution is best made from a known potable water source; however, sodium hypochorite can also effectively sterilize locally obtained ground water.

Irrigation of open fractures and wounds with field water treated with sodium hypochlorite to a concentration of 0.025% will safely and effectively eliminate water borne bacteria. Additionally, Heggers et al. have proven this concentration to be not only bactericidal but also non-toxic to host tissues.[14] This field-expedient modification of "Dakin's solution," made from locally obtained water sources of opportunity, including ground water if necessary, may substitute for sterile saline when adequate supplies are neither available nor logistically feasible, thus eliminating the need to carry large volumes of irrigation fluid forward.

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